EPICS Process Database

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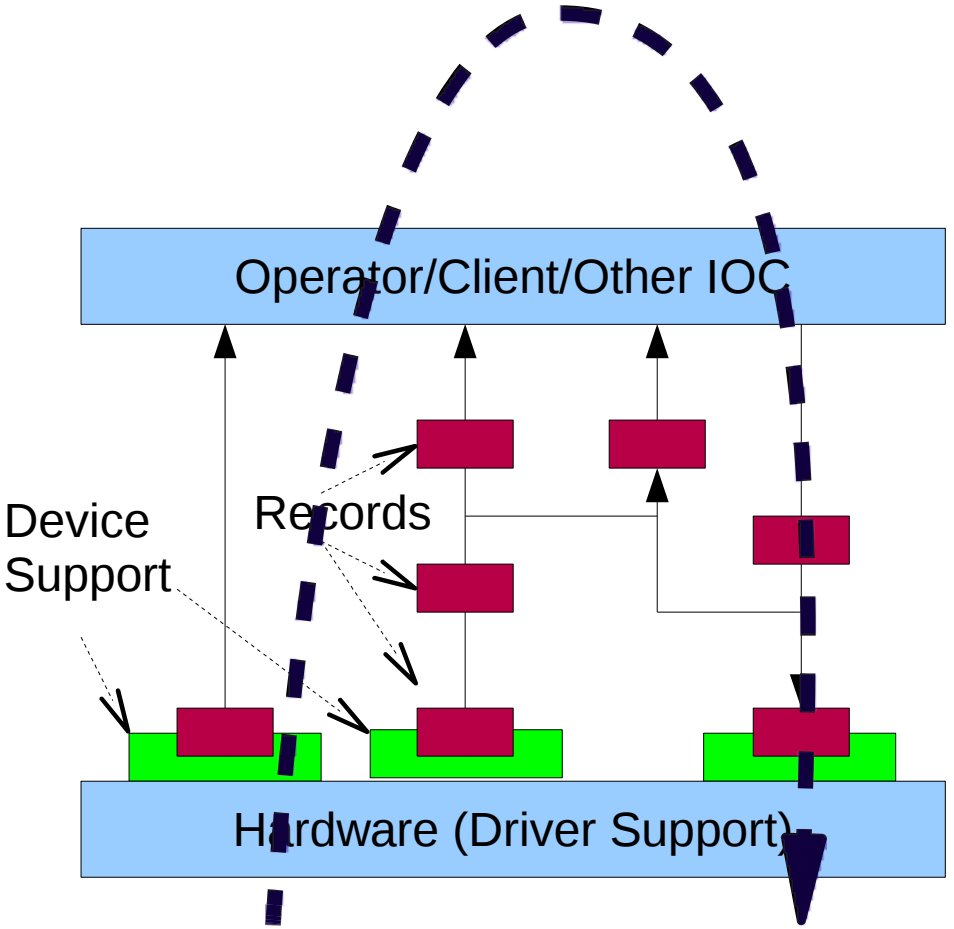
Goals

- Understand .db file and IOC shell syntax
- Be able to follow the flow of a database
- Add/modify an alarm condition
- Add a calcout record to modify a value

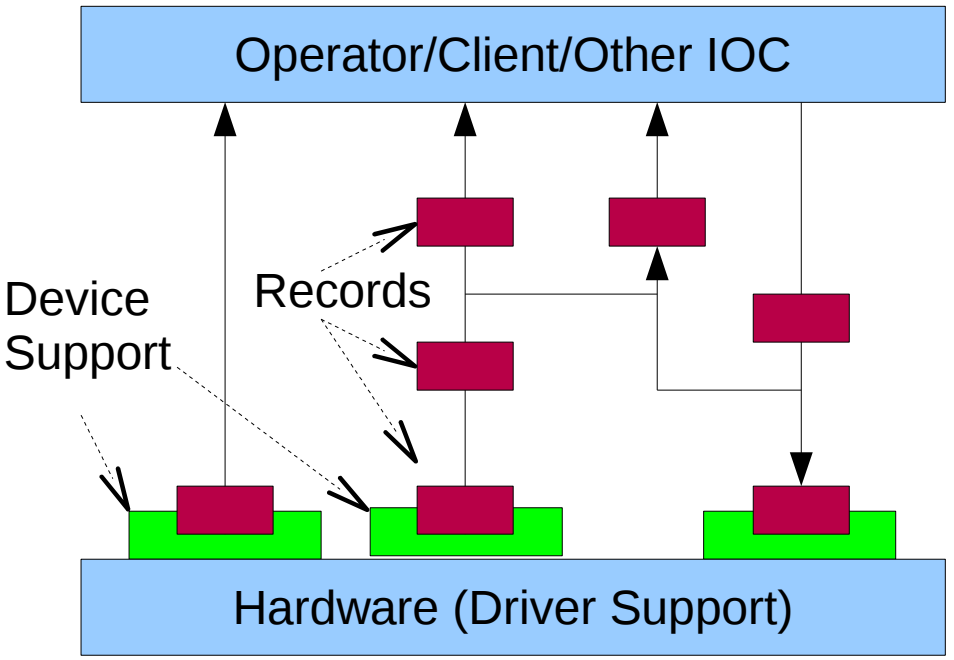
- Examples
  - https://pubweb.bnl.gov/~mdavidsaver/training-201010.tar.gz

IOC Data Pipeline



- Configuration vs. Compilation
- Modular
- Database
  - Data (Configuration)
- Device Support
  - Operations
    - Modify DB
    - Access HW
  - Stateless (ideally)
- Driver Support
  - Catch-all

In the Database



- Record
  - Collection of fields
  - Recordtype
  - Many have devSup
- Fields
  - Atomic value (int, …)
  - Scalar, array, or link
  - Attributes (eg. PP)
- Record+Field=Process Variable

In the Database

```
record(ai, “myrecord:v17”) {
        field(DESC, “neat”)
        field(DTYP, “mydev”)
        field(INP, “#C1 S7 @v”)
}
```

- Record
  - Collection of fields
  - Recordtype
  - Many have devSup
- Fields
  - Atomic value (int, …)
  - Scalar, array, or link
  - Attributes (eg. PP)

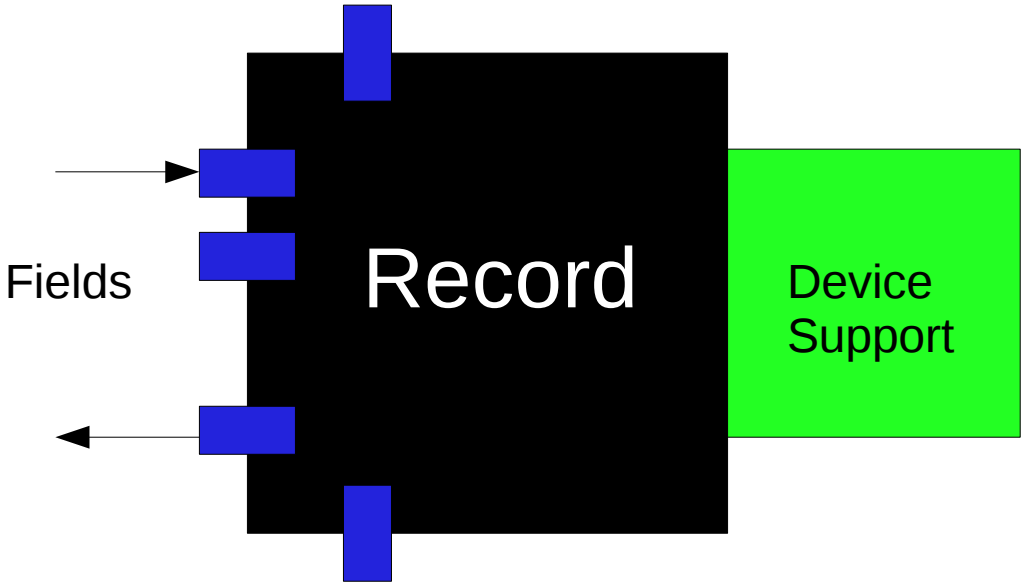
Record+Field=Process Variable

RDB Translation

- Process DB is an object database with an integrated client (device support).
- In terms of a relational database
- recordtype → table
- record → row
- field → column
- link → foreign key (???)
  - FK is a cell (column+row) pointing to a row.
  - A Link is a cell pointing to another cell.

What is a record?

- A record is the basic unit of “action” in a database
- Field values modify the action



- Records do
- Fields store

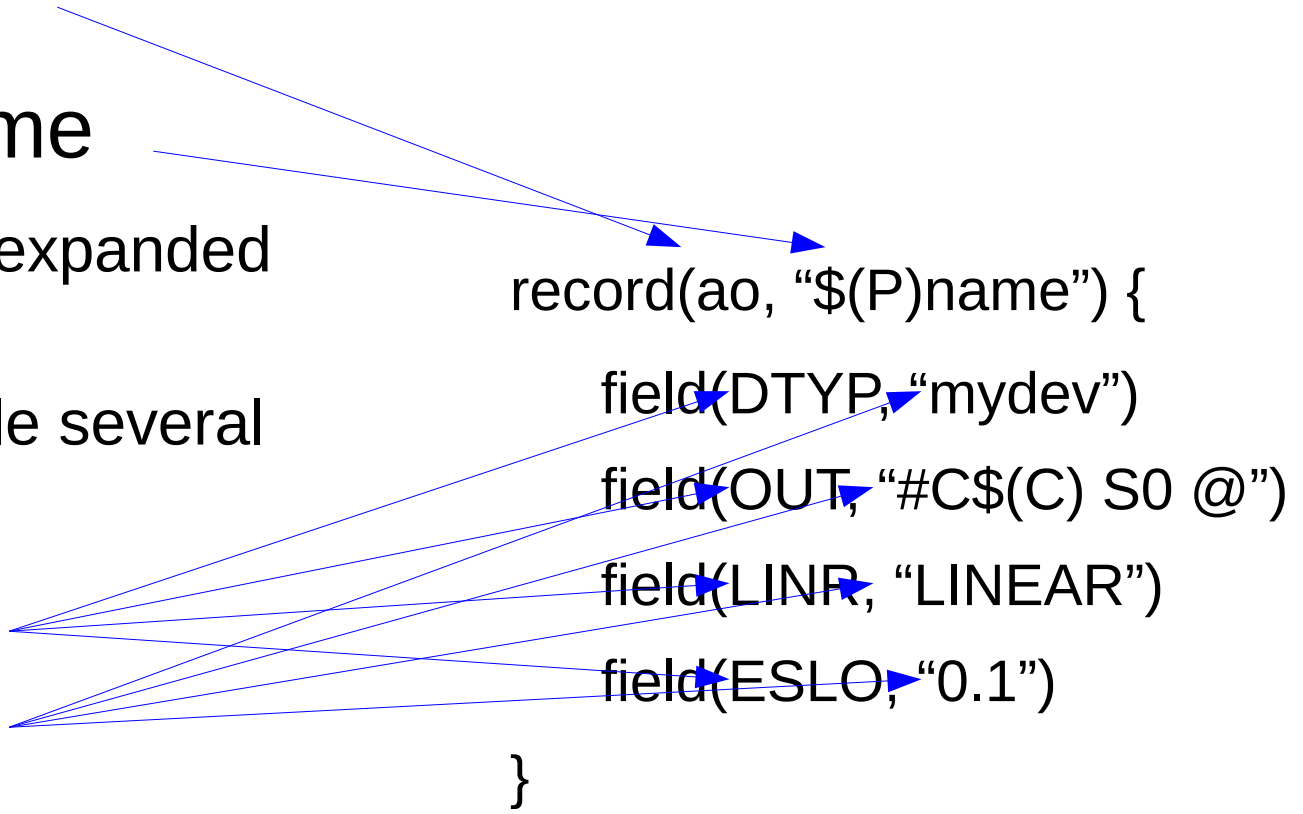
Device Support

- Compiled (C/C++)
- Associated with a record
- Use pre-defined set of hooks

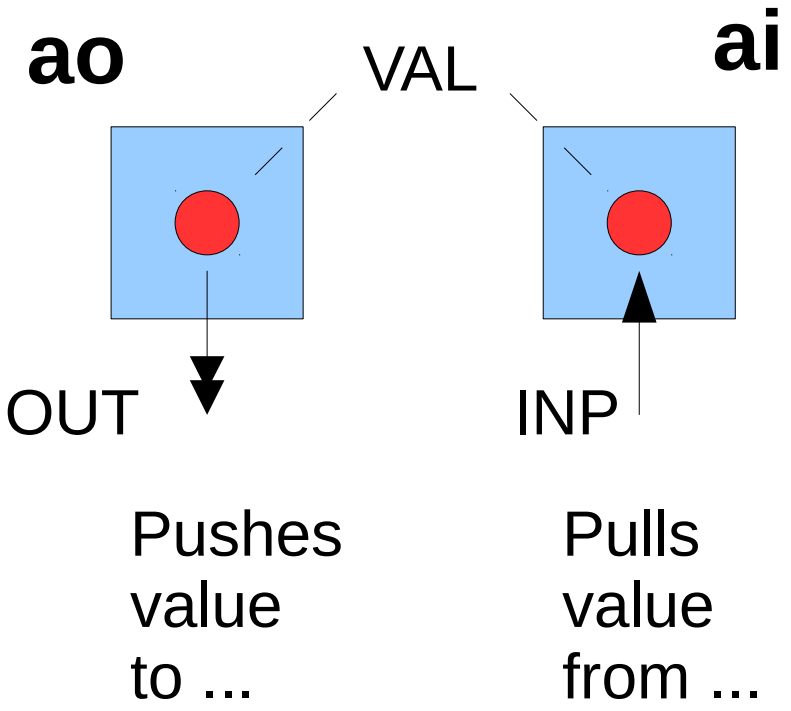
- API
  - report()
  - init()
  - init_record()
  - get_iointr_info()
  - process()
    - read()
    - write()

Db Syntax

- Recordtype
- Instance name
  - $(P) macros expanded when loaded
  - Load same file several times
- Field name
- Field value
  - Always quote

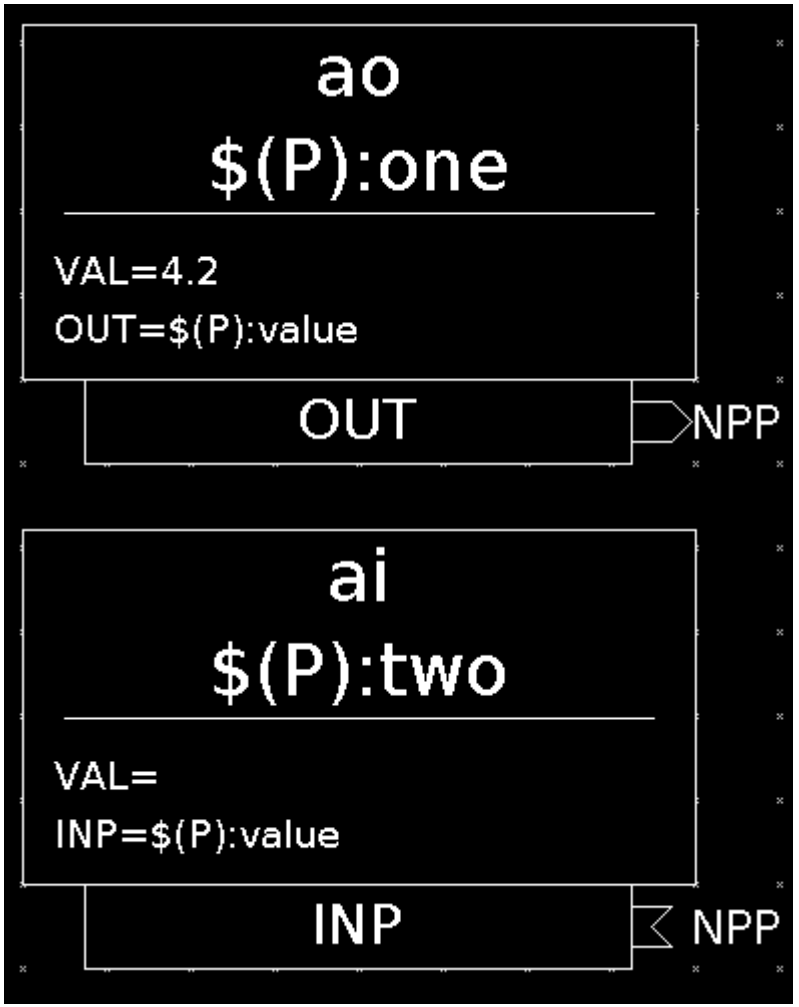


Simple recordtypes



- Analog (float)
  - ao, ai
- Binary
  - bo, bi, mbbo, mbbi
- Integer (32-bit)
  - longout, longin

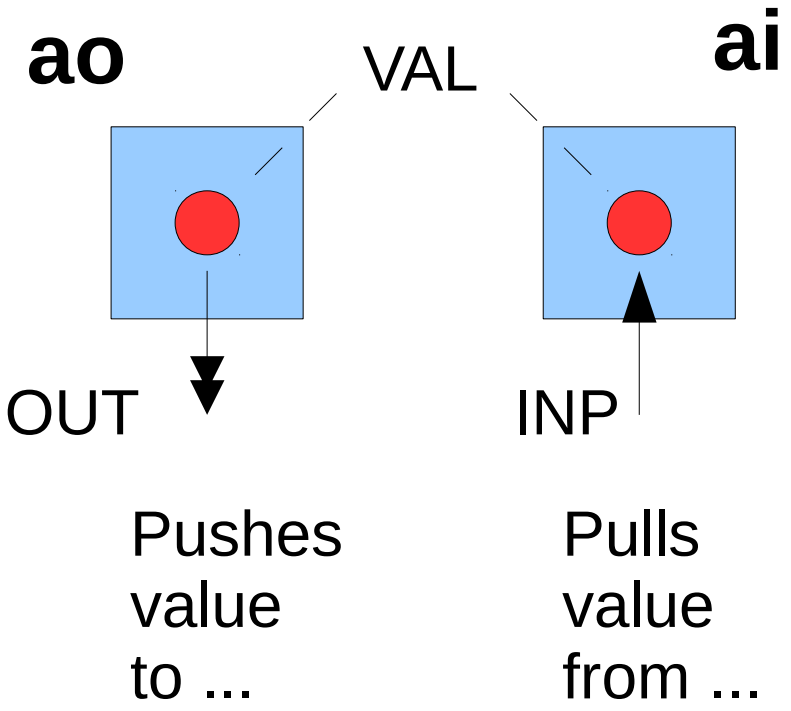
Simple recordtypes



- Analog (float)
  - ao, ai
- Binary
  - bo, bi, mbbo, mbbi
- Integer (32-bit)
  - longout, longin

In VDCT

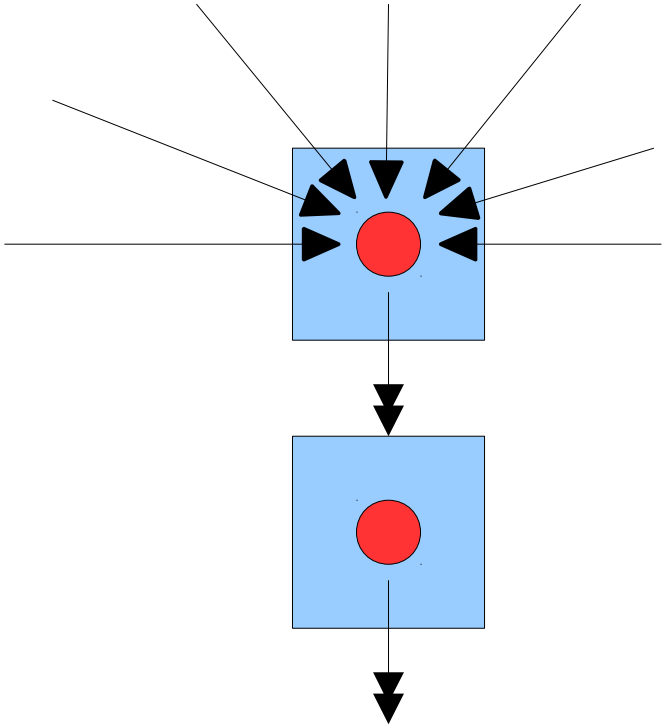
Simple recordtypes (2)



- Input
  - VAL=read(INP)
  - Operator reads VAL
- Output
  - Operator sets VAL
  - write(OUT,VAL)
- Address (INP/OUT)

Calculator Record

- recordtype: calcout
- 12 Input links (A-L)
- 1 Output link (OUT)
- Result stored in VAL
- CALC field
  - (A-B)/(A+B)
  - Length limit (40 char)
- Changeable at runtime
- OUT, OCALC, OVAL will be explained later



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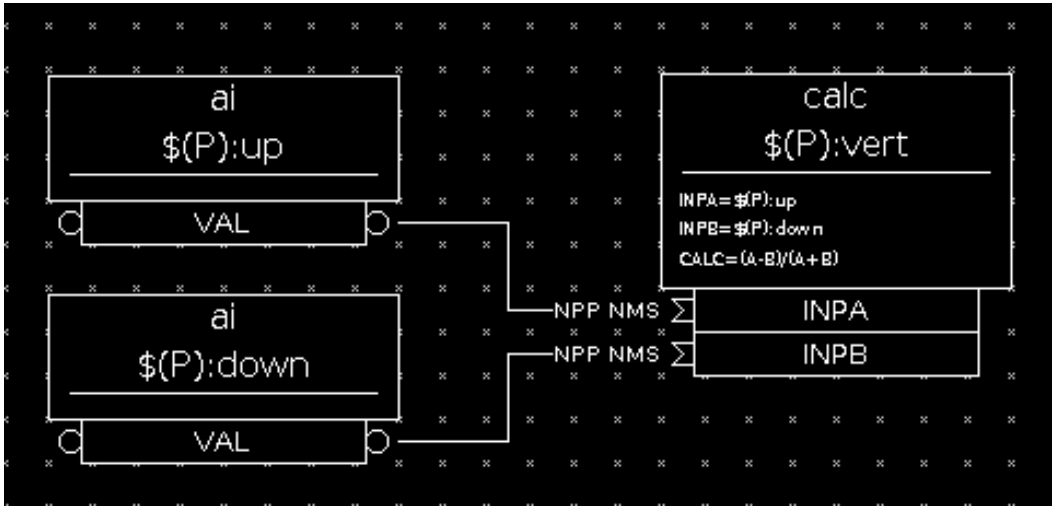
```
record(ai, “bpm:up”) {
}
record(ai, “bpm:down”) {
}
record(calcout, “bpm:y”) {
    field(INPA, “bpm:up”)
    field(INPB, “bpm:down”)
    field(CALC, “(A-B)/(A+B)”)
}
```

Full list of CALC expression syntax in record reference manual

Calculator Record




```
record(ai, “bpm:up”) {
}
record(ai, “bpm:down”) {
}
record(calcout, “bpm:y”) {
    field(INPA, “bpm:up”)
    field(INPB, “bpm:down”)
    field(CALC, “(A-B)/(A+B)”)
}
```

Full list of CALC expression syntax in record reference manual

Exercise 1 – softIoc Basics

- Executable: softIoc
- Part of EPICS Base
- No device support

Useful utilities from EPICS Base

caget, camonitor, caput, cainfo

The Counter

- Start script: count.cmd

  dbLoadRecords(“count.db”, “P=myprefix”)

  iocInit()

Select your own

- Database: count.db

```
record(calcout, “$(P):count”) {
    field(SCAN, “1 second”)
    field(VAL, “7”)
    field(INPA, “$(P):count.VAL NPP”)
    field(INPB, “2”)
    field(CALC, “A+B”)
}
```

Full list of CALC expression syntax in record reference manual

- Simple 1 Hz counter

  softIoc count.cmd

- Things to try

  camonitor myprefix:count

  caput myprefix:count.SCAN

  “.1 second”

  caput myprefix:count.B -2

Extending Counter

- Things to try
- Make the counter roll over

  Use “cond ? true : false”

  Set limits

  field(HOPR, “10”)

  field(LOPR, “0”)

- Examine CA meta-data
- caget -d GR_DOUBLE myprefix:count
- caget -d GR_ENUM myprefix:count.SCAN
- caget -a myprefix:count

Database Scanning

- Cause processing
- When actions happen
  - Inputs read
  - Outputs written
  - Value conversion
  - Alarms checked
- Defined per record
  - SCAN field
- Conditions
  - Periodic timer
    - 1 second, 10 second, ...
  - HW interrupt
    - I/O Intr
  - Passive
    - More in a moment

Scan Examples

```
record(bi, “status..”) {
    field(SCAN, “1 second”)
    field(INP, “some:other”)
}

record(ai, “level..”) {
    field(SCAN, “I/O Intr”)
    field(DTYP, “myadc”)
    field(INP, “#C1 S0 @adc”)
}
```

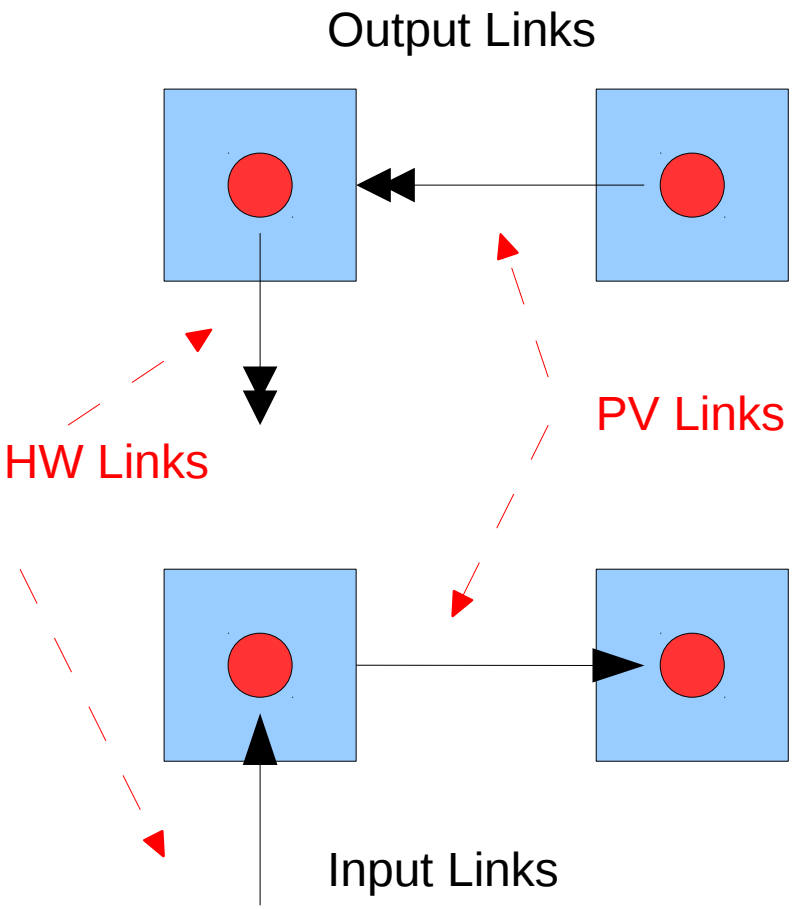
Device Support must know which “interrupt” source to use

```
record(ao, “gain..”) {
    field(SCAN, “Passive”)
    field(DTYP, “mydac”)
    field(INP, “#C1 S0 @gain”)
}
```

Passive Scan

- Actions which can cause a Passive record to process
  - A 'Get'
  - A 'Put'
  - A forward link (more in moment)
- Things which can cause...
  - A DB link from another record
  - A CA client (another IOC, caget, EDM, BOY, …)
  - The difference: None

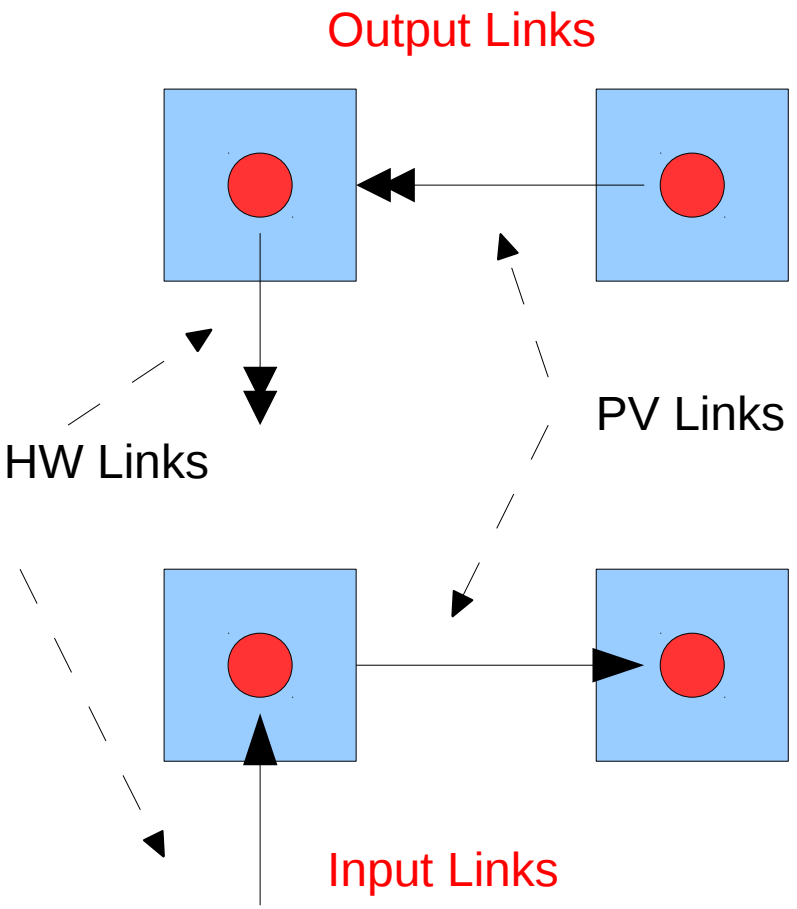
Link Types



- PV Link
  - Connect to another field
  - Any field (almost)
  - Any IOC
  - Local or Remote link
- Hardware Link
  - Token for devSup
  - Identifies (card 7, port 2)

A Link is the least common denominator of a local function call and and CA get/put

Link Types (2)



- Output Link
  - Put data
  - write value to referenced field
- Input Link
  - Get data
  - Read value from referenced field
- Forward Link
  - Cause process()

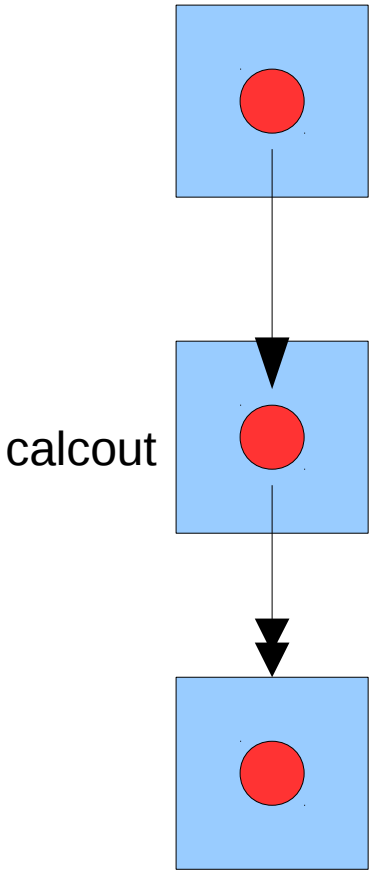
A Link is the least common denominator of a local function call and and CA get/put

Constant Links

- Output
  - No action
- Input
  - Read a constant value (default 0)
  - Store in associated value field (INPA → A)

```
record(calcout, “bpm:y”) {
    field(INPA, “bpm:up”)
    field(INPB, “bpm:down”)
    field(INPC, “14”)
    field(CALC, “(A-B)/(A+B+C)”)
}
```

Scanning and Links



- Link attributes (PP or NPP)
- Input Links
  - NPP – Read current field value.
  - PP – Process then read new field value
- Output Links
  - NPP – Write field.
  - PP – Write field then process using new value.
- Default is NPP

Process Passive Links

- field(INP, “name NPP”)
  - Gets current value
- field(INP, “name PP”)
  - If 'name' is SCAN Passive then process()
  - Gets new value
- field(OUT, “name NPP”)
  - Sets new value
- field(OUT, “name PP”)
  - Sets new value
  - If Passive then process()

Forward Links

- NPP Links transfer data
- PP Links transfer data and causes processing
- Forward links only causes processing
- Every record has 1 (FLNK)
  - fanout has 8

```
record(bi, “bit1”) {
    field(SCAN, “1 second”)
    field(FLNK, “bit2”)
}
record(bi, “bit2”) {
    field(FLNK, “bit3”)
}
record(bi, “bit3”) {
}
```

Link Types (3)

Input Link

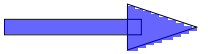
PV Link — Read a value from a field

HW Link — Read a value from a device/driver

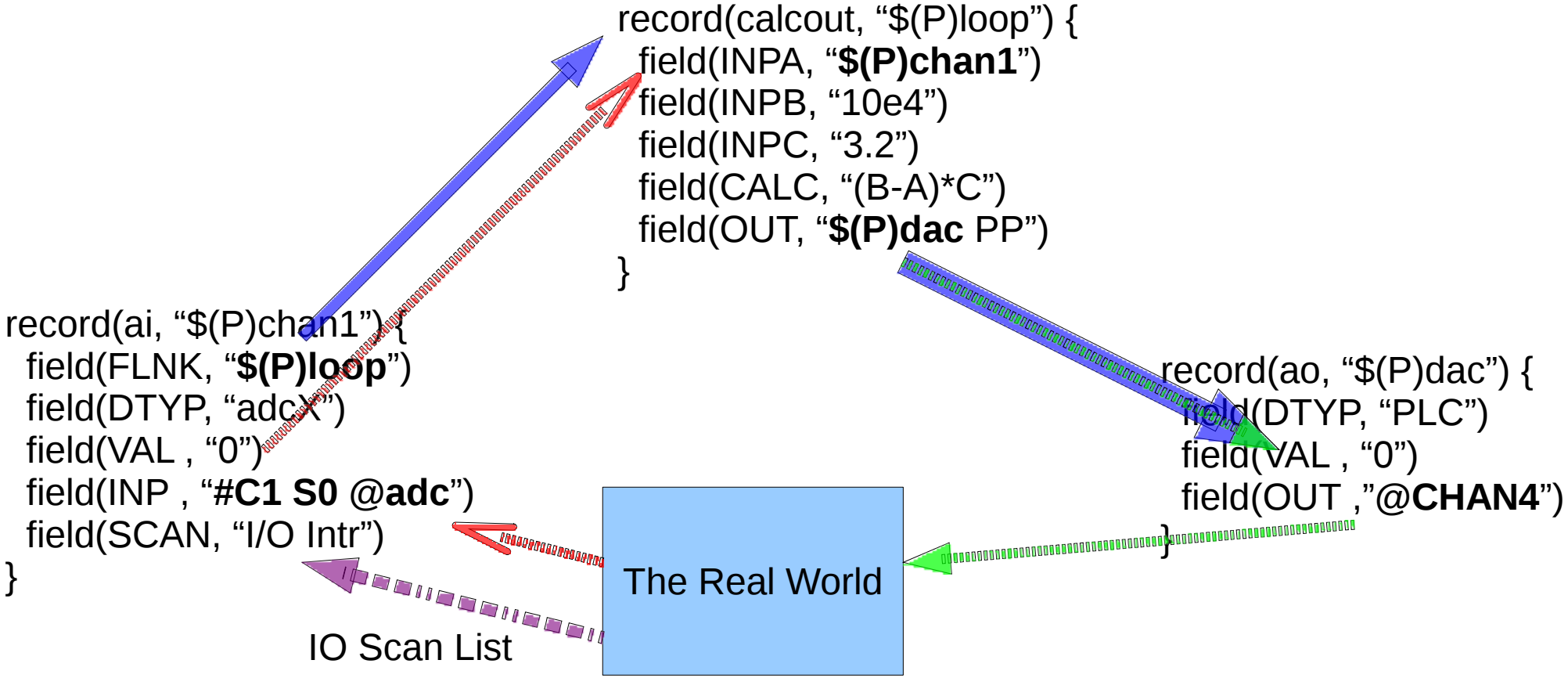
Output Link

Write a value to a field

Write a value to a device/driver



“Process” Link



Record Processing Chains

- In most databases most records (~50%) don't belong to a processing chain.
- Processing chains are usually short (2-3 records).
- Most databases have a few longer chains.

Add process chain examples
Pass 1 overview
Pass 2 step through

Exercise 2 – Random numbers

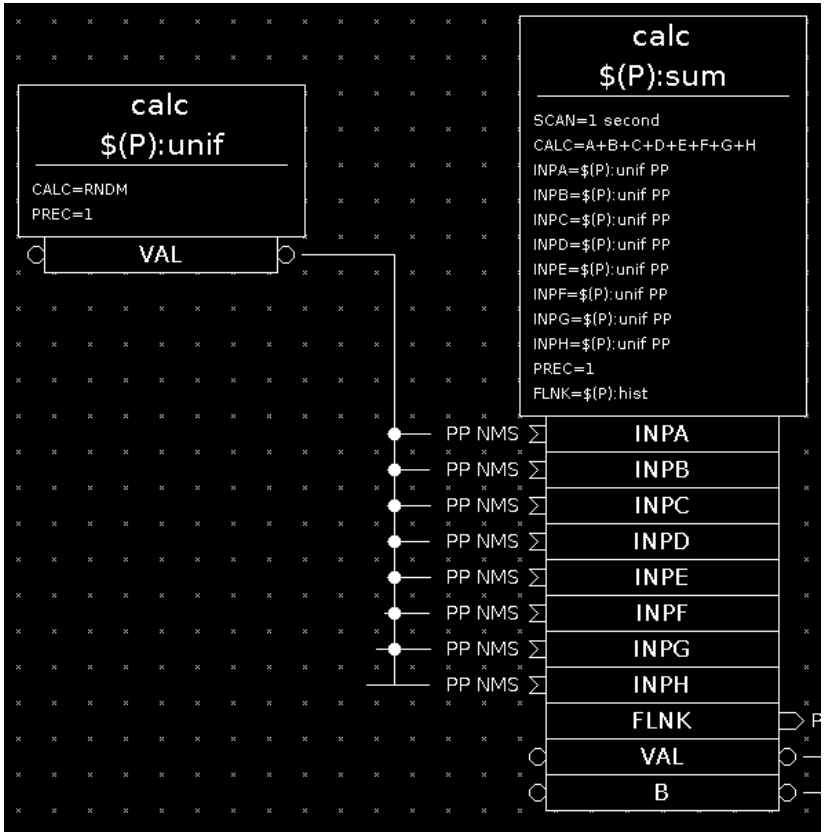
- calc expressions can contain 'RNDM' to generate a uniform random number [0,1].

  field(CALC, “RNDM”)

- A Gaussian distribution can be approximated by summing 8 such numbers.
- What does '$(P):sum' in gauss.db actually use.

Example 2 – Database

```
record(calc, "$(P):unif") {
  field(CALC, "RNDM")
  field(PREC, "1")
}
```



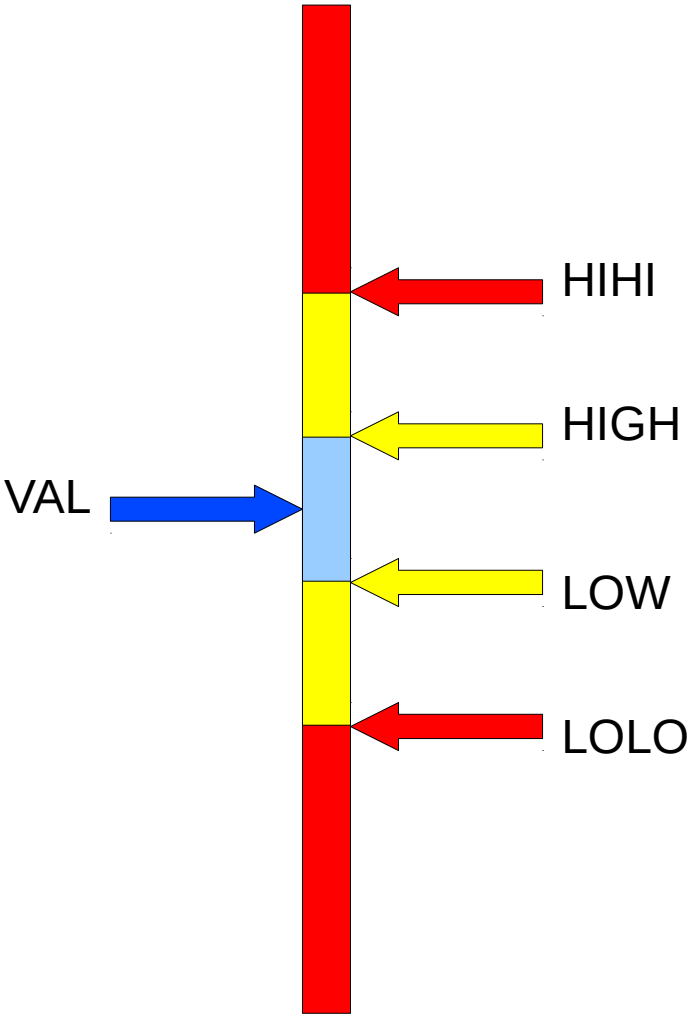

```
record(calc, "$(P):sum") {
  field(SCAN, "1 second")
  field(CALC, "A+B+C+D+E+F+G+H")
  field(INPA, "$(P):unif")
  field(INPB, "$(P):unif")
  field(INPC, "$(P):unif")
  field(INPD, "$(P):unif")
  field(INPE, "$(P):unif")
  field(INPF, "$(P):unif”)
  field(INPG, "$(P):unif")
  field(INPH, "$(P):unif")
  field(PREC, "1")
  field(FLNK, "$(P):hist")
}
```

Alarms

- Each record has an alarm severity and status
- Severity: NO_ALARM, MINOR, MAJOR, INVALID
- Status: READ, WRITE, LINK, …
- Conditions defined in record and device support
- Highest severity shown

Value Level Alarms

- For ao,ai, longout, longin
- Severity
  - NO_ALARM, MINOR, MAJOR, INVALID
  - Default: NO_ALARM
- Levels
  - HIHI, HIGH, LOW, LOLO



Value Level Alarms

- For ao,ai, longout, longin
- Severity
  - NO_ALARM, MINOR, MAJOR, INVALID
  - Default: NO_ALARM
- Levels
  - HIHI, HIGH, LOW, LOLO

```
record(ai, “my:adc”) {
    field(HIGH, “14”)
    field(HSV, “MINOR”)
    field(LOW, “-12”)
    field(LSV, “MAJOR”)
}
```

Invalid Alarms

- For: ao, bo, calcout, mbbo, stringout
- IVOA
  - Continue Normally
  - Don't drive outputs
  - Set output to IVOV
- IVOV
  - Same type as VAL

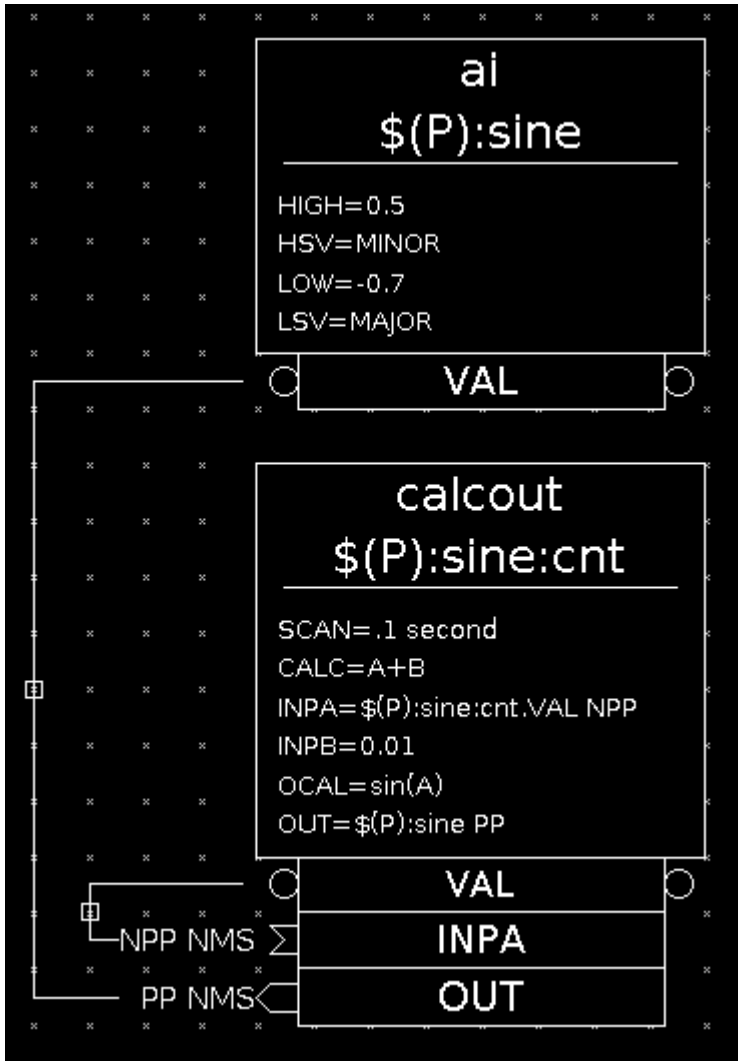
Doesn't clip like DRVH DRVL

```
record(ao, “my:dac”) {
    field(HIGH, “255”)
    field(HSV, “INVALID”)
    field(LOW, “0”)
    field(LSV, “INVALID”)
    field(IVOA, “Set output to IVOV”)
    field(IVOV, “0”)
}
```

Exercise 3 – Sine

- Use a counter calcout and another calcout record to generate a sine wave.
- Set a minor alarm when >0.5 and a major alarm when <-0.7
- Use only one calcout for both count and sine (Hint: OCAL and OVAL fields)

Exercise 3 – Database




```
record(calcout, "$(P):sine:cnt") {
  field(SCAN, ".1 second")
  field(CALC, "A+B")
  field(INPA, "$(P):sine:cnt.VAL NPP")
  field(INPB, "0.01")
  field(OCAL, "sin(A)")
  field(OUT , "$(P):sine PP")
}

record(ai, "$(P):sine") {
  field(HIGH, "0.5")
  field(HSV , "MINOR")
  field(LOW , "-0.7")
  field(LSV , "MAJOR")
}
```

Link and Alarms

- Link attribute MS/NMS
- NMS (default)
  - Just get/put the value
- MS
  - Get/put value and alarm severity
- Propagate Alarms

```
record(ai, “one”) {
    field(HIGH, “10”)
    field(HSV, “MINOR”)
}

record(ai, “two”) {
    field(INP, “one MS PP”)
    field(SCAN, “1 second”)
}
```

Analog Scaling

- For: ao, ai
- Go from RVAL (integer) → VAL (float)
  - field(DTYP, “Raw Soft Channel”)
  - Some other device support
- Players: LINR, ROFF, ASLO, AOFF, ESLO, EOFF
- VAL=(RVAL+ROFF)*ASLO+AOFF
- If LINR=”LINEAR”
- VAL=ESLO*VAL+EOFF
- EGU=”some string”

Analog Scaling Example

```
record(ai, “adc1”) {
    field(DTYP, “myadc”)
    field(ASLO, “0.1”)
    field(AOFF, “10”)
    field(ESLO, “”)
    field(EOFF, “”)
    field(EGU, “F”)
}
```

- ADC calibration
  - 0.1 degrees/count
  - Count 0 is 10 deg. C
- C → F

Record Timestamps

- Each record has one timestamp
  - Shared by all fields
- Updated when processed
  - NOT when values change
  - Defaults to 0 (Jan. 1 1990) until first processed
- Problem for non-value fields
  - camonitor recname.SCAN
- Makes archiving these fields tricky

Controlling Timestamps

- Fields:
  - TSEL – Timestamp selection input link
  - TSE – Timestamp Event
  - TIME – Stored time (Not directly readable)
- Choose where timestamp is taken from
  - Uses generalTime framework (>= 3.14.9)

Timestamp Selection

```
/* recGblTimeStamp() */
If TSEL is not CONSTANT
    if TSEL points to a TIME field
        TIME=dbGetTimeStamp(TSEL)
        return
    TSE=dbGetLink(TSEL)
if TSE != -2
    TIME=epicsTimeGetEvent(TSE)
return
```

Special hidden TSEL link option

Takes time from record pointer or CA metadata

Read an integer to use as the event number

Takes time of last occurrence of event #

generalTime Events

- Normal events: 1-32k
  - **Not** database events
  - Hooks to event timing system (if present)
  - No default provider
- Special events
  - 0 – Current wall clock time
  - -1 – Best event time (???)
  - -2 – Allow device support to set TIME

TS Examples (1)

- Current wall clock time
  - Default

```
record(ai, “name”) {
    …
}
```

- Specific gT event

```
record(ai, “name”) {
    field(TSE, “42”)
}
```

- From another record

```
record(calc, “name”) {
    field(INPA, “other.VAL”)
    field(TSEL, “other.TIME”)
}
```

- Take event # from another record

```
record(calc, “name”) {
    field(TSEL, “other.TSE”)
}
```

TSEL and CA_LINK

- Potential mistake if 'aaa' and 'bbb' are in the same IOC.
- Example 1 (Wrong)
  - aaa.TSEL is DB_LINK
  - 'aaa' and 'bbb' in same lock set
  - Timestamp may not match value
- Example 2 (Right)
  - aaa.TSEL is CA_LINK
  - 'aaa' and 'bbb' in different lock sets
- Rule: **TSEL must use same type of link as value link.**

```
record(calc, “aaa”) {
    field(INPA, “bbb CPP”)
    field(TSEL, “bbb.TIME”)
}
```

Copies latest
From record struct

```
record(calc, “aaa”) {
    field(INPA, “bbb CPP”)
    field(TSEL, “bbb.TIME CA”)
}
```

Uses meta-data
from previous
monitor/get.

Set Timestamp is Device Support

- Set TSE to -2

```
record(ai, “aaa”) {
    field(TSE, “-2”)
}
```

- In dset

```
read_ai(aiRecord* prec) {
    if(prec->tse==epicsTimeEventDeviceTime) { /* -2 */
        prec->time.secPastEpoch=... /* Use EPICS Epoch (Jan 1 1990) */
        prec->time.nsec=...
    }
}
```

Common Record Fields

- Device support: DTYP, INP, OUT
- Links: INP, OUT
- Scanning
  - SCAN, PINI, PACT
- Values: VAL, OVAL, RVAL, RBV, RRBV
- Alarms
  - STAT, SEVR
  - HIHI, HIGH, LOW, LOLO
  - HHSV (high high severity), HSV, LSV, LLSV
- Value+Alarm
  - IVOA (invalid out action), IVOV (invalid out value)
- Display: EGU, DRVH, DRVL